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# JxB FORCE EFFECTS ON BERYLLIUM MELT SPLASHING IN FUSION DEVICES

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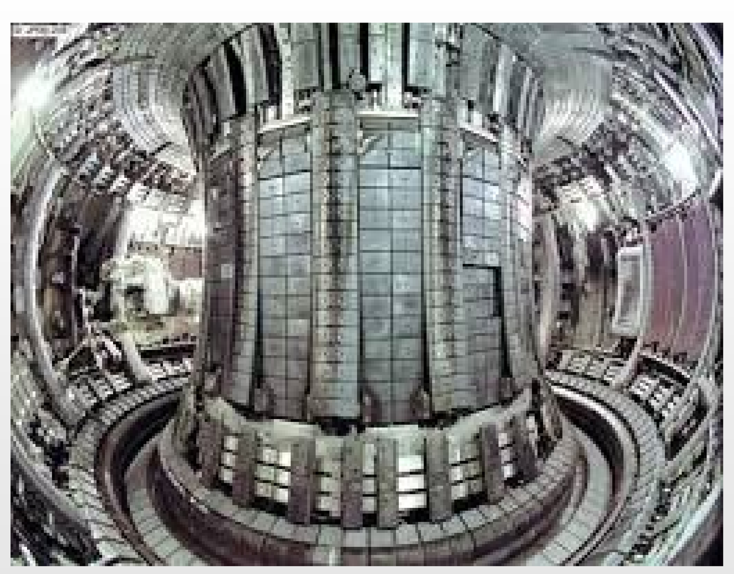
## Abstract

Instability and disruption of high-temperature plasma in fusion devices may result in the edge-localized modes (ELMs) and lead to melting of plasma facing components (PFCs) causing their damage. Beryllium (Be) is used as a first wall for PFCs due to its low density, high strength, and high thermal conductivity. However, melting of Be on the surface of first wall is of a great concern as splashing of a molten Be layer will result in the plasma contamination and termination of fusion reaction. Therefore, it is important to understand the physics mechanisms characterizing the splashing of Be from a pool under the plasma impact in a strong magnetic field as that in the International Thermonuclear Experimental Reactor (ITER). The computational model that combines the volume of fluid (VoF) and magneto-hydrodynamic (MHD) models is used to simulate the effects of thermal, viscous, gravitational and surface tension forces on the molten Be layer. The additional source terms representing the external and thermo-emission currents are also implemented. These currents are taken into consideration as they contribute to the electromagnetic JxB force and may result in faster melt motion, redistribution, and splashing. In this work, the effects of JxB forces on splashing of molten Be, development and growth of waves, and ejection of molten droplets are examined. The stimulation results show the motion of molten Be layer and development waves at the vapor-melt interface. Results may complement the experiments at Joint European Torus (JET) and studies of PFCs melt layer phenomenon for ITER program.


## Background and Motivation



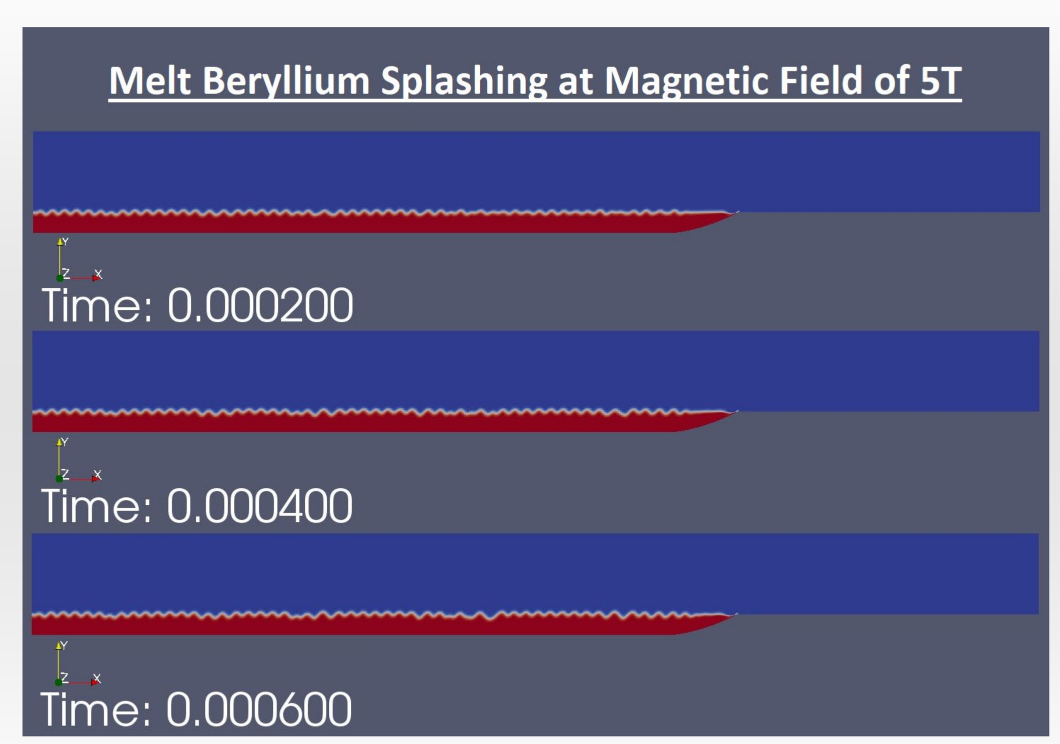
- **ITER:** International Thermonuclear Experimental Reactor, the frontier of tokamak fusion reactor
- **JET:** Joint European Torus, conduct research and experiment on tokamak design and support the progress of ITER program
- **PFC:** Plasma facing component in fusion reactor to withstand high temperature, pressure and magnetic field during fusion reaction
- **Beryllium:** Material which is used for interior first wall of tokamak reactor due to its unique properties
- **JxB Force:** The resulting force due to current density and magnetic flux density which occurs in magnetic confinement fusion reactor during operation
- **Geometric Factor:** Should be considered because the motion of splashing will be affected by the location where melt Be is formed

## Computational Model


- **Eclipse IDE:** Primarily used for developing C++ computer code
- **OpenFOAM:** Initially, created by Henry Weller in 1989 at Imperial College, London
  - OpenFOAM is a C++ toolbox for the development of customized numerical solvers
  - It contains many pre-built and ready-to-use solvers which designed to solve partial differential equations (PDE) for continuum mechanics and CFD problems
  - OpenFOAM also consists of many pre-processing and post-processing utilities which are designed to perform tasks involving data manipulation before and after CFD simulation
  - Can be used in other areas such as solid dynamics, molecular dynamics and Monte Carlo problems, electromagnetics, pricing of financial options
- **ParaView:** An open-source multiple-platform application which used to analyze and generate visual image through the input datasets
- **Set up of the simulation:**
- Initially, create a melt Be layer (red region) at the material surface
- Set thickness of Be layer to be 0.2 mm
- Temperature of the layer is set as 1560 K which is the melting point of Beryllium
- The background pressure for the whole system is set to p = 1 bar and the applied magnetic field is B = 5 T
- Stream of viscous plasma with a velocity of 100 $ms^{-1}$ impacts Be-melt layer moving with a speed of 2 $ms^{-1}$

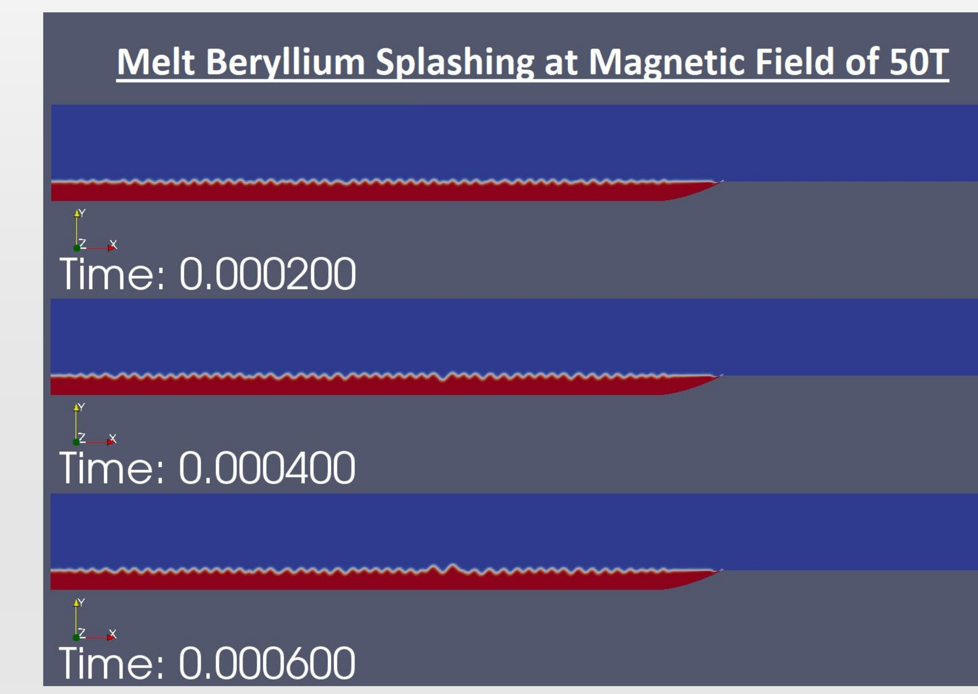
## Motion of Melt Beryllium at Magnetic Field of 5T

- **The motion of melt Be is closely monitored at different time interval**
- At 0.2ms, small altitude waves start to form at the liquid surface
- As the time progresses, the waves are affected by the magnetic field and begins to fluctuate
- However, with the given amount of magnetic force, the melt Be layer does not have significant splashing at time of 0.6ms

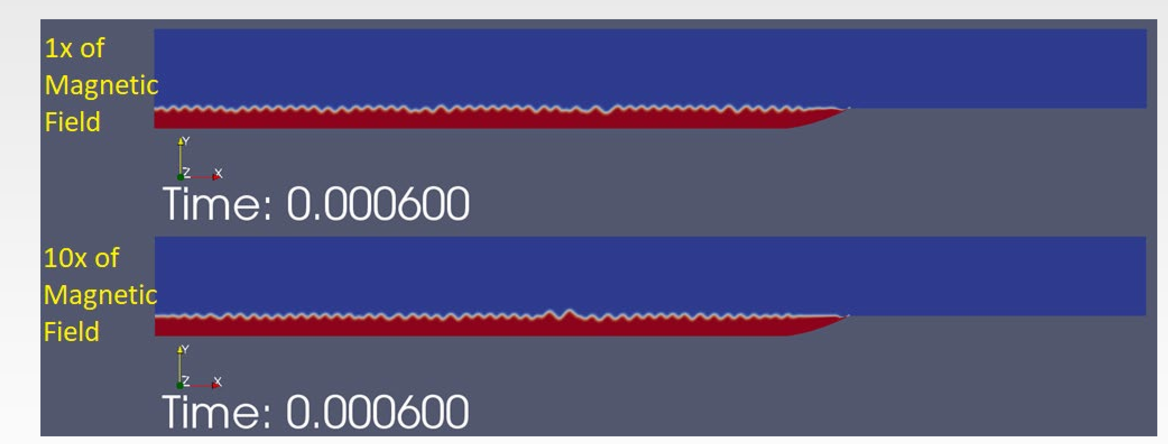



## Motion of Melt Beryllium under Higher Magnetic Field


- Similar to lower magnetic field simulation, waves are formed due to the influence of JxB force
- Starts from 0.4ms, higher number of high altitude waves begin to form.




## Comparison of Motion of Melt Beryllium Splashing at Different JxB Force




- At 0.6ms, surface of the liquid Be under higher JxB force starts to produce significantly higher waves
- The waves signal that the melt Be responds to the higher JxB force and splashing will occur at an earlier stage than lower JxB force condition

## Conclusions

- Wave pattern starts to form at the surface of melt Be layer within a short period of time (<0.2ms)
- As the liquid Be continues its exposure to magnetic field, the motion of the layer variates as well
- Under the influence of higher JxB force, splashing will happen faster as higher altitude waves occur as early as 0.6ms


## Acknowledgment

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